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Invention: DATA TRANSMISSION METHODS IN A TELECOMMUNICATION SYSTEM

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SPECIFICATION

DATA TRANSMISSION METHODS IN A TELECOMMUNICATION SYSTEM

The invention relates to data transmission in telecommunication systems and particularly in radio systems.

5   Mobile communication systems generally refer to different telecommunication systems which enable personal wireless data transmission while subscribers roam in the system area. A typical mobile communication system is a Public Land Mobile Network (PLMN). First-generation mobile communication systems were analogue systems where speech or data was

10   transferred in an analogue form similarly as in conventional public switched telephone networks. An example of a first-generation system is the Nordic Mobile Telephone (NMT).

In second-generation mobile systems, such as the Global System for Mobile Communication (GSM), speech and data are transmitted in a digital

15   form. In addition to conventional speech transmission, digital mobile communication systems provide a plurality of other services: short messages, facsimile, data transmission, etc.

Currently under development are third-generation mobile communication systems, such as the Universal Mobile Communication System

20   (UMTS) and the Future Public Land Mobile Telecommunication System (FPLMTS), which was later renamed as the International Mobile Telecommunication 2000 (IMT-2000). The UMTS is being standardized by the European Telecommunication Standards Institute (ETSI), whereas the International Telecommunication Union (ITU) standardizes the IMT-2000

25   system. These future systems are basically very similar. For example the UMTS, as all mobile communication systems, provides wireless data transmission services to mobile subscribers. The system supports roaming, which means that UMTS users can be reached and they can make calls anywhere as long as they are situated within the coverage area of the UMTS.

30   Services provided by mobile communication systems can generally be divided into teleservices and bearer services. A bearer service is a telecommunication service which forms signal transmission between user-network interfaces. For example modem services are bearer services. In a teleservice the network also provides subscriber terminal services. Important

35   teleservices include speech, facsimile and videotex services. Bearer services are usually divided into groups according to a property, such as asynchronous

and synchronous bearer services. Each of these groups comprises a number of bearer services, such as a transparent service (T) and a non-transparent service (NT). In a transparent service the (real-time) data to be transmitted is unstructured and transmission errors are corrected only by means of channel

5 coding. In a non-transparent service the (non-real-time) data to be transmitted is structured into protocol data units (PDU) and transmission errors are corrected by utilizing (in addition to channel coding) automatic retransmission protocols, i.e. retransmission of corrupted data in the data link layer. For example in the GSM system such a link protocol is called a radio link protocol

10 (RLP). This kind of link protocol is also generally referred to as link access control (LAC), particularly in connection with third-generation mobile communication systems.

In a retransmission protocol the data is transmitted in frames (data units), which usually comprise a frame check sequence FCS, which is

15 calculated on the basis of the frame content. The receiver checks the content of the received frames by calculating the FCS on the basis of the content of the received frame and by comparing it with the FCS received in the frame. If the FCSs do not match, the frame is interpreted as corrupted and the receiver requests for retransmission of the frame. The receiver also requests for

20 retransmission when the frame is missing entirely. In such a manner the radio system is able to provide a user with a data channel which has a better bit error ratio (BER) than a data channel with no retransmission protocol in use. For example in the GSM system, the basic BER (without RLP) is usually about 10^{-3}, whereas with the use of RLP the BER is about 10^{-8}. On the other hand,

25 the effective data rate naturally deteriorates due to numerous retransmissions.

The retransmission protocol retransmits the entire frame whenever the FCS calculated in the receiver does not match the received FCS. This may result from an error of one bit in the frame. This speaks for the use of short frames in order that the amount of data that is possibly retransmitted as a

30 result of bit errors can be minimized. On the other hand, each frame has a header, which contains sequence numbers for identifying the frame, and an FCS field. This overhead, in turn, speaks for longer frames in order that the overhead in the frames can be minimized. The longer the frames, the smaller the portion of the overhead with respect to the amount of the data to be

35 transmitted. At present there are protocols which employ fixed-length data frames (such as the GSM RLP) and protocols utilizing variable-length

protocols, such as Logic Link Control LLC in the packet data service GPRS of the GSM system.

Third-generation mobile communication systems may require variable-length frames of the data link layer for different reasons, for example
5 in order to achieve optimum adaptation to changing conditions of an underlying Medium Access Control (MAC) layer and to varying radio conditions. In third-generation systems it is possible to use different MAC services with different BERs from about 10^{-3} to 10^{-6} with or without MAC layer retransmission. However, there is a problem related to adaptive changing of
10 the frame length.

If the radio conditions deteriorate, the frame length is made shorter. The shorter the frame, the less susceptible it is to disturbance and the greater the likelihood that the frame is transmitted over the radio path without distortion. On the other hand, if the frames are very long each frame is
15 subjected to bit errors during the transmission and the transmission only consists of retransmissions. When the frame length changes during the connection, it is likely that the transmission buffers will contain long frames waiting for retransmission. However, such long frames cannot be divided into several short frames since this would make the frame numbering meaningless
20 and thus prevent correct operation. In other words, if long frames that have already been transmitted are retransmitted in short frames with different frame numbers, it will confuse the complicated sequences of retransmissions and retransmission requests, possibly resulting in loss or doubling of data. Therefore long frames must be retransmitted even if the optimum frame length
25 used by the new frames may be considerably shorter.

Transfer to the use of third-generation mobile communication systems will take place gradually. At the beginning, third-generation radio access networks will be used in connection with network infrastructure of second-generation mobile communication systems. Such a hybrid system is
30 illustrated in Figure 1. A second-generation mobile services switching centre MSC is connected both to a second-generation radio access network, such as a GSM base station system BSS consisting of a base station controller BSC and base stations BTS, and to a third-generation radio access network consisting of, for example, a radio network controller RNC and base stations
35 BS. In practice, there will be two different radio subsystems RSS, which share a common infrastructure on the network subsystem NSS level. Second-

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generation mobile stations MS (such as the GSM) communicate via the second-generation radio access network and third-generation mobile stations MS (such as the UMTS) communicate via the third-generation radio access network. Possible dual-mode phones (such as GSM/UMTS) are able to use
5 either radio access network and to perform handovers between them.

Since a third-generation radio access network has not been designed to be compatible with a second-generation core network (NSS), it is clear that such a mixed architecture requires interworking between the networks, usually described in the form of an interworking unit IWU. A general
10 requirement is that no modifications are allowed in the second-generation system (mobile services switching centre MSC), which means that the interface connecting, for example, the GSM MSC and the IWU should be a pure A interface. The IWU should carry out all the conversions between the second-generation and third-generation functions and formats. Since the
15 second-generation and third-generation retransmission protocols (such as RLP and LAC) will be at least somewhat different, interworking which will probably be needed between the second-generation and third-generation systems is the adaptation of these different protocols to each other.

Subsequent development will lead to a situation where pure third-
20 generation mobile communication networks exist in parallel with second-generation mobile systems or the aforementioned hybrid systems. Figure 2 illustrates this situation.

An object in the development of third-generation mobile communication systems is supporting a handover between second-generation
25 and third-generation mobile systems. A dual-mode mobile station should be able to roam from a second-generation radio access network to a third-generation radio access network and vice versa without a break in an ongoing call.

This object can be reached rather easily for speech calls or
30 transparent data calls. A handover causes loss or doubling of only a few bits when traffic channel protocol stacks are being swapped. Speech does not require amendment of these few bit errors, since they only cause a momentary disturbance or no noticeable change in the received speech. In transparent data transmission, end-to-end application protocols correct single bit errors.
35 The situation is different when a handover is carried out for non-transparent data calls. As stated above, NT calls utilize a retransmitting link

protocol, such as RLP or LAC, (in addition to channel coding) for error correction. Second-generation and third-generation protocols will be at least somewhat different. Therefore it is necessary to change the link protocol during a handover. However, in a handover there may be complicated ongoing

5   sequences of selective retransmissions and retransmission requests in the "old" link protocol, and an interruption thereof possibly leads to loss or doubling of data. Yet, in order to maintain data integrity it is important that not one bit is lost or doubled during the swap of the traffic channel protocol stacks.

An object of the invention is to eliminate the problems related to the

10   retransmission of old frames when the frame length of the retransmission protocol is changed during the connection.

Another object of the invention is the interworking between link layer protocols of different radio systems.

Yet another object of the invention is to develop a handover method

15   which maintains data integrity in a handover for a non-transparent call between two mobile communication systems.

The basic idea of the invention is to utilize "payload unit numbering" instead of or in addition to conventional frame numbering. The data is split into fixed-length data blocks or payload units. The size of a block is preferably

20   equal to or smaller than the shortest information field in the frames of the protocol(s) used. Each protocol frame carries one or more payload units. In an optimum situation the length of the information field in a protocol frame equals n * the length of the payload unit, where n is an integer. Instead of (in some special cases possibly in addition to) frame numbering the protocol frame

25   carries payload numbers both for indicating the payload units (data blocks) transferred in the protocol frame and for acknowledgement of the received blocks.

The payload numbering according to the invention is thus based on the numbering of the units formed from the data content, wherefore it is

30   independent of the frame length and the frame type, i.e. the used protocol. This provides considerable advantages.

By means of the payload numbering it is possible to avoid the aforementioned problems related to changing the length of the protocol frame. After the frame length has changed, the transmitter splits the "old" frames in

35   the retransmission buffer back into payload units, packs these payload units into "new" frames and indicates with payload numbering in the header of the

new frame which payload units the frame contains (e.g. by indicating the number of the first payload unit in the frame). The receiver identifies the change in the frame length (e.g. from the frame header) and the payload numbers (both the numbers sent for identification of the received frames and

5   the numbers sent for acknowledgement) from the frame header similarly as before the change of the frame length. The retransmission sequences are not disturbed as a result of the change in the frame length since the payload numbering is the same as before the change. The only thing that changes is the frame capacity, i.e. the number of payload units transferred in one frame.

10 Therefore the invention optimizes the performance of a non-transparent data traffic channel under varying radio and error conditions.

By means of the payload unit numbering it is also possible to improve the interworking of link layer protocols between two different radio systems. The length of the payload unit can be selected optimally regarding

15 the protocols used by both systems. For example, the length of the payload unit can be negotiated at the start of each connection in the same way as all the other link layer parameters, or the length can be indicated directly or indirectly in connection with signalling, or the length can be fixed. In an embodiment of the invention, a radio access network (e.g. a third-generation

20 radio access network) where the protocol (e.g. LAC) allows changing the frame length is connected to another radio system (e.g. a second-generation radio system) where the protocol (e.g. RLP) frame has a fixed length. The length of the payload unit can be selected to be identical to the length of the information field in the RLP frame, in which case each RLP frame carries one

25 payload unit and the payload numbering is directly compatible with the RLP frame numbering. Therefore the same numbering applies over the entire connection for example between the mobile station and the mobile services switching centre even though the connection comprises two legs with different layer 2 link protocols and even different frame lengths. This simplifies the

30 implementation of the interworking between the systems since the interworking does not have to adapt two different frame numbering systems to each other, but it only attends to the adaptation of the different protocol functions and formats and to the transmission of information (user data and protocol commands and responses). If either protocol does not support a particular

35 protocol function, the interworking unit can deactivate the function for example by means of negative acknowledgement when the link parameters are being

negotiated at the beginning of the connection. Also, the same numbering from end to end enables handovers without loss or doubling of data. Alternatively, the length of the payload unit can be selected such that the frame of the first protocol (e.g. third-generation LAC) can be transmitted through a channel of

5   the second radio system instead of the second protocol (e.g. RLP) frame or in the information field thereof. In this case, too, the same numbering is applied from end to end, which provides several advantages. The invention also makes it possible to change the frame length at the radio interface in steps of a payload unit even though the frame length at the network interface between

-10   the mobile services switching centre and the interworking unit stays the same. Therefore the frame length at the radio interface can be adapted to radio conditions, error conditions, etc.

          The payload units are numbered preferably in ascending order. Therefore, under normal conditions it is sufficient that the payload units in the

15   frame are identified with one payload unit number (e.g. the number of the first payload unit). In such a case the invention causes no or only minimum overhead. A different situation occurs when the data rate is changed from a lower to a higher rate or vice versa, and the higher data rate is not an even multiple of the lower data rate. In such a case there may be scattered payload

20   units (which are no longer in the original sequence), which must be retransmitted. According to an embodiment of the invention, in these less than optimum situations the payload unit number is indicated in the frame separately for each payload unit by means of so-called header extension. This means a temporary increase in overhead. However, these situations are rare

25   since only about 5 to 10% of the frames are assumed to be retransmitted and only a fraction of these will be out of sequence and subject to changes of data rate.

          The invention will be described below in greater detail in connection with preferred embodiments, with reference to the accompanying drawings, in

30   which

          Figure 1 shows a second-generation mobile communication network supplemented with a third-generation radio access network;

          Figure 2 shows a second-generation and a third-generation network between which dual-mode mobile stations can roam;

35   Figure 3 shows a protocol stack of a non-transparent data service in the GSM system;

Figure 4 shows protocol layers of a third-generation mobile system
in another manner;

Figure 5 illustrates a basic structure of an LAC frame;

Figures 6A to 6C illustrate payload unit numbering according to the

5   invention;

Figure 7 illustrates data transmission and retransmission based on
payload numbering;

Figures 8A, 8B, 8C and 9 illustrate the retransmission according to
the invention when the frame length changes;

10   Figure 10 shows a mobile communication system where a third-
generation radio access network is connected to a second-generation mobile
services switching centre;

Figure 11 shows data transmission in the system of Figure 10 when
payload unit numbering is used;

15   Figure 12 illustrates a handover according to the invention during
the transmission of an LAC frame;

Figure 13 illustrates an extendible header of a protocol frame; and

Figure 14 shows a frame where the header comprises individual
numbers of four payload units.

20   The present invention can be applied in any telecommunication
system with a link protocol frame of variable length, or in interworking or
handover between any two digital radio systems with different radio link
protocols. "Radio system" should be understood broadly such that different
radio access networks of the same mobile network are able to form different

25   radio systems, as illustrated in Figure 1, or that radio systems refer to entirely
separate mobile communication systems, as shown in Figure 2. One or both of
the radio access networks can be wireless local loop (WLL) or radio local loop
(RLL) networks. The primary field of application of the invention is a handover
between a second-generation and a third-generation mobile network, such as

30   the GSM and the UMTS. "Link protocol" should also be understood herein
generally to cover not only the present second-generation protocols, such as
the RLP of the GSM system, but also all the possible third-generation or later
generation link access control (LAC) protocols or the radio link control protocol
(RLCP) of the Wideband CDMA system, or also lower-layer retransmission

35   protocols, such as the medium access control (MAC). In the following, the
preferred embodiments of the invention will be described by using as an

example the second-generation GSM system and the third-generation UMTS. In the description below, the GSM radio link protocol will be called RLP and the UMTS radio link protocol will be called LAC.

5   A GSM network consists of two basic parts: a base station system BSS and a network subsystem NSS. The BSS and the mobile stations MS communicate via radio connections. In the BSS, each cell is served by a base station BTS. A number of BTSs are connected to a base station controller BSC the function of which is to control radio frequencies and channels used by a BTS. The BSCs are connected to a mobile services switching centre MSC.

10   Certain MSCs are connected to other telecommunication networks, such as the public switched telephone network PSTN, and they comprise gateway functions for calls terminating at and originating from these networks. These MSCs are known as gateway-MSCs (GMSC). There are also at least two databases: a home location register HLR and a visitor location register VLR.

15   A mobile communication system comprises adapter functions for adapting an intra-network data link to the protocols used by terminal equipments and other telecommunication networks. The adapter functions typically include a terminal adaptation function TAF placed at the interface between a mobile station and a data terminal equipment connected thereto,

20   and an interworking function IWF situated at the interface between the mobile network and another telecommunication network, usually in connection with an MSC. In the GSM system a data link is set up between a TAF of the MS and an IWF in the mobile network. The TAF adapts a data terminal equipment DTE connected or integrated to the MS to the aforementioned GSM data link that is

25   set up over a physical connection using one or several traffic channels. The IWF connects the GSM data link for example to another telecommunication network, such as an ISDN or another GSM network, or to some other transit network, such as a PSTN.

Figure 3 illustrates protocols and functions required for non-

30   transparent bearer services. A non-transparent circuit switched connection between a TAF and an IWF on a GSM traffic channel comprises several protocol layers that are common to all these services. They include different rate adaptation RA functions, such as RA1' between the TAF and a channel codec unit CCU placed in the BSS, RA1 between the CCU and the IWF, RAA

35   (or RAA' for a 14.4 kbit/s channel) between the CCU and a transcoder unit TRAU placed remote from the base station, and RA2 between the TRAU and

the IWF. The rate adaptation functions RA are defined in the GSM recommendations 04.21 and 08.20. Communication between the CCU and the TRAU is defined in the GSM recommendation 08.60. Information that has been RA1' rate-adapted in the radio interface is also channel-coded as defined

5   in the GSM recommendation 5.03, which is illustrated by blocks FEC in the MS and the CCU. The IWF and the TAF also comprise higher-level protocols that are specific to each service. In an asynchronous non-transparent bearer service the IWF requires an L2R (Layer 2 Relay) protocol and a radio link protocol RLP and a modem or a rate adapter towards the fixed network. The

10 L2R functionality for non-transparent character oriented protocols is defined for example in the GSM recommendation 07.02. The RLP is defined in the GSM recommendation 04.22. The RLP is a frame-structured, balanced (HDLC-type) data transmission protocol, where error correction is based on retransmission of distorted frames at the request of the receiving party. The

15 interface between the IWF and for example an audio modem MODEM is as defined in CCITT V.24 and it is denoted in Figure 3 by L2. This non-transparent configuration is also used to access the Internet.

The RA1 and RA1' rate adaptations map each 240-bit RLP frame into four modified 80-bit V.110 frames (between the MSC and the BSS) or into

20 four modified 60-bit V.110 frames (at the radio interface). A bit sequence called "Frame Start Identifier" is used to indicate which V.110 frame in the bit stream is the first one for a particular RLP frame. The first quarter of the RLP frame is transmitted in this V.110 frame, the second quarter is transmitted in the next frame, the third quarter in the third frame and the fourth one in the

25 fourth frame, whereafter a new RLP frame begins.

In the HSCSD concept of the GSM system, a high-speed data signal is divided into separate data streams, which are then transmitted via N subchannels (N traffic channel time slots) at the radio interface. When the data streams have been divided they are conveyed in the subchannels as if they

30 were mutually independent until they are again combined in the IWF or the MS. However, logically these N subchannels belong to the same HSCSD connection, i.e. they form one HSCSD traffic channel. According to the GSM recommendations dividing and combining a data stream are carried out in a modified RLP, which is thus common to all the subchannels. Below this

35 common RLP each subchannel comprises separately the same protocol stack RA1'-FEC-FEC-RA1'-RAA-RAA-RA2-RA2-RA1, which is shown in Figure 3 for

one traffic channel between the MS/TAF and the MSC/IWF. Therefore an HSCSD traffic channel according to the GSM recommendations will still use the common RLP for the different subchannels even though the bit rate on a single subchannel can be as high as 64 kbit/s.

5   An example of a third-generation network is the UMTS, which is still under development. It should be noted that the detailed structure of the UMTS access network is not significant for the invention. According to the simplest scenario the UMTS is an access network the functions of which are strictly limited to radio access functions. Therefore it mainly comprises functions for

10   controlling radio resources (handover, paging) and for controlling bearer services (radio network service control). The more complicated functions, such as registers, register functions, mobility management and location management, are placed in a separate network subsystem NSS or in the core network. The NSS or the core network may be, for example, the GSM

15   infrastructure. In Figures 1 and 2 the third-generation radio access network comprises base stations BS and a radio network controller RNC. It is further assumed that the third-generation system employs the link access control LAC protocol between the MS and the MSC/IWF, the protocol differing from second-generation radio link protocols, such as the RLP. A physical traffic

20   channel comprises lower protocols, in the frames of which the LAC frames are transmitted. In principle a protocol stack of a third-generation mobile communication system may be similar as described above in connection with the GSM system, except that RLP is replaced with LAC.

Figure 4 illustrates in another manner protocol layers of a pure third-

25   generation mobile communication system. The LAC protocol extends from end to end between an MS and an MSC. At the radio interface between the MS and the BS/RNC there is MAC (Medium Access Control) and a physical layer (radio channel) below the LAC. At the network interface between the BS/RNC and the MSC there is a transmission layer and a physical layer (transmission

30   channel) below the LAC. Figure 5 shows a basic structure of an LAC frame comprising a fixed-length header, a variable-length information field, and a fixed-length frame check sequence FCS. It is possible that in third-generation systems the LAC throughput is optimized under varying radio conditions by manipulating the length of the LAC frame. Generally, there can be two reasons

35   for changing conditions: different radio environments and different MAC bearer services. At the start of a connection it is possible to use for optimum frame

size a default value based on connection parameters. During the connection it is possible to monitor the quality of the data transmission, for example the frame error ratio (FER). If the FER drops below a predetermined limit indicating good conditions, the frame size is increased. If the FER exceeds

5   another predetermined limit, the frame size is decreased. With such an arrangement the LAC tries to optimize the frame size for the radio conditions and bit error ratio in each case. However, there may be specified maximum and minimum values for the frame size, depending on the bit rate. If the data is not transmitted sufficiently rapidly for some reason, the actual frame size can

10   be smaller than the optimum frame size in order to avoid delays. The MAC layer can also indicate the present conditions, thus helping the LAC to adapt more rapidly. The optimum frame size can be the same or different for different transmission directions, which means that both ends are able to negotiate the optimum frame size or each end uses its own optimum frame size. It should be

15   noted that the arrangement described above is only a scenario of the inventors concerning the adjustment of the frame length. It is not essential to the invention how the frame length is changed. The invention can also be applied in situations where the frame length is fixed or agreed upon only at the start of the connection.

20   Figures 6A to 6C illustrate the payload unit numbering according to the invention. A transmitter splits a data stream 61 to be transmitted into fixed-length data blocks or payload units 62. The size of the payload unit 62 is preferably equal to or smaller than the shortest information field in the frames of the used protocol(s), such as the LAC. The transmitter and/or the receiver

25   obtains the length of the payload unit directly or indirectly from outband or inband signalling. The length can also be negotiated at the beginning of the connection or again during the connection. The payload units 62 are inserted into the information field of LAC frames 63. Therefore each LAC frame 63 carries one or more payload units 62. In an optimum situation the length of the

30   information field in the LAC frame 63 equals n * the length of the payload unit 62, wherein n is an integer. For example in Figure 6C, the LAC frames comprise n payload units. Each LAC frame 63 further comprises a frame check sequence FCS. Instead of frame numbering the LAC frame carries in the header field H the payload unit numbering indicating which payload units

35   are transferred in the information field of the LAC frame. In the example shown in Figure 6C, the numbering in the header field, i.e. a so-called transmission

number, indicates that in addition to the number of the first payload unit 62, e.g. number 1, the header of the LAC frame can contain the data that the information field of the LAC frame comprises n payload units. The receiver can also conclude itself the number of the payload units in the frame, it can know

5   the number in advance or it can receive information in some other manner. On the basis of the transmission number and the information on the number of payload units, the receiver is able to calculate the numbers of the other payload units in the frame, if necessary, and the number of the next payload unit it wants. The receiver can transmit this next number, i.e. a so-called

10   reception number, in acknowledgement to the transmitter if the LAC frame was received successfully. As a result of the acknowledgement the transmitter transmits the requested payload unit and n-1 next payload units in the next LAC frame. If the FCS indicates that the content of the received LAC frame was faulty or if the frame is missing entirely, the receiver can request for

15   retransmission of the entire LAC frame by sending in acknowledgement the transmission number given in the faulty frame. If it can be concluded from the FCS that the faulty bit is in the kth payload unit (where k is an integer and k≤n), the receiver can transmit the number of this corrupted payload unit in acknowledgement in an embodiment of the invention. As a result of the

20   acknowledgement the transmitter retransmits the requested payload unit and (n-k+1) following payload units together with (k-1) new payload units in the next LAC frame. If the data transmission is bidirectional, the above-described operation can take place in both transmission directions. In such a case the header H of the LAC frames 63 may contain both a transmission number for

25   one transmission direction and a reception number for the other transmission direction. Further, it is possible to use windowing with the payload numbers similarly as in the protocols based on frame numbers.

Figure 7 shows an example of data transmission and retransmission based on the payload numbering according to the invention. A

30   transmitter Tx transmits an LAC frame 71, which comprises three payload units, numbers 1, 2 and 3, and it stores the LAC frame 71 or only the payload units 1 to 3 in a retransmission buffer. The header of the LAC frame 71 indicates the number of the first payload unit, i.e. number 1. A receiver Rx receives the LAC frame without errors and transmits an LAC

35   acknowledgement frame 72, where the header indicates the number of the next desired payload unit, i.e. number 4. The transmitter Tx transmits the next

LAC frame 73, which contains payload units 4, 5 and 6, and it stores the LAC frame 73 or only payload units 4 and 5 in the retransmission buffer. The reception of the entire LAC frame 73 fails and the receiver Rx transmits an LAC acknowledgement frame 74 where payload unit 4 is again requested for.

5   The transmitter Tx retransmits payload units 4, 5 and 6 in an LAC frame 75.

Figures 8A, 8B and 8C illustrate how a transmitter Lx processes frames to be retransmitted when the frame length is changed during the connection. Figure 8A shows an "old" frame in the transmission buffer, comprising n payload units. After the frame length has changed, the

10   transmitter Tx splits the "old" frame back into payload units (Figure 8B) and packs the payload numbers into "new" frames, each of which comprises two payload units (Figure 8C). The payload numbering in the header of the new frame indicates which payload units the new frame comprises.

Figure 9 shows an example of the data transmission and

15   retransmission according to the invention, based on payload numbering, when the frame length changes in the middle of the transmission. LAC frames 71 to 74 are transmitted in the same manner as in Figure 7. After LAC frame 73 has been transmitted, the frame length is shortened such that only two payload units are transmitted in one new frame instead of the old three units. After the

20   frame length has changed, the transmitter Tx receives an acknowledgement frame 74 requesting for retransmission of payload units 4 to 6. The transmitter Tx unpacks the old LAC frame 73 as shown in Figure 8 and inserts payload units 4 and 5 into a new LAC frame 91, which is transmitted to the receiver Rx. The receiver Rx acknowledges with an LAC frame 92, where payload unit 6 is

25   requested for next. The transmitter Tx transmits an LAC frame 93 containing the payload unit 6 to be retransmitted and a new payload unit 7. The retransmissions could thus be carried out without interference to the retransmission sequences as a result of the changed LAC frame length, since the payload numbering and the modes of the transmitter and the receiver

30   remain the same after the change. The only thing that changes is the LAC frame throughput, i.e. the number of the payload units transferred in one LAC frame.

By means of the payload numbering it is also possible to improve the interworking of link layer protocols between two different radio systems.

35   Figure 10 shows a mobile communication system where a third-generation radio access network is connected to a second-generation mobile services

switching centre MSC. The radio access network supports the link access control LAC protocol and the MSC supports the radio link protocol RLP. Between the radio access network and the MSC there is an interworking function described in the form of an interworking unit IWU. The LAC protocol is
5   applied between the MS and the IWU. The RLP protocol is applied between the IWU and the MSC. The IWU comprises an LAC/RLP function which understands both the LAC and the RLP formats and converts the transmission formats and functions between the LAC and the RLP. If a particular function is supported by only one of the protocols, the IWU preferably deactivates such a
10   function during the protocol negotiations. Therefore all the functions operate from end to end between the MS and the IWU.

According to the invention, the LAC frames carry data in fixed-length payload units, as described above. Also, the retransmission mechanism between the MS and the IWU is based on payload numbering and not on LAC
15   frame numbering. The length of a payload unit equals the length of an information field in an RLP frame. This means that one RLP frame carries one payload unit. When the retransmission mechanism between the IWU and the MSC employs conventional RLP numbering, the payload numbering is directly compatible with the RLP frame numbering. Therefore the same numbering
20   applies over the entire connection between the MS and the MSC despite two different protocols. In other words, the RLP and the LAC process the same sequence numbers (the sequence numbers are synchronized) even though the LAC frames can be longer than the RLP frames. The IWU does not independently acknowledge the data it has received from the MS or the MSC,
25   but it only performs a format conversion and forwards the information to the receiver, regardless of whether the information is user data, acknowledgements or protocol commands/responses.

Figure 11 illustrates the data transmission according to the invention in a network configuration of the type shown in Figure 10. An MS
30   transmits an LAC frame 111 comprising three payload units, numbers 1 to 3. The header of the frame 111 indicates that the first payload unit is number 1. The IWU receives the LAC frame 111, unpacks payload units 1 to 3 from the frame 111 and packs them into three RLP frames 112, 113 and 114, the frame numbers of which are correspondingly 1, 2 and 3. The RLP frames are
35   inserted into a transmission buffer. The IWU transmits the first RLP frame (frame number 1) to the MSC. The MSC acknowledges successful reception

with an RLP frame 115, where frame number 2 is requested for next. Since such a frame is found in the transmission buffer, the IWU transmits a second RLP frame (frame number 2) to the MSC. The MSC acknowledges successful reception with an RLP frame 116, where frame number 3 is requested for next.

5   Since such a frame is found in the transmission buffer, the IWU transmits a third RLP frame (frame number 3) to the MSC. The MSC acknowledges successful reception with an RLP frame 117, where frame number 4 is requested for next. This exchange of RLP frames is shown without the use of windowing, but the changes it causes in the operation are evident to those

10   skilled in the art. In the windowing the IWU transmits for example all the RLP frames 112 to 114 one after another (the size of a window is three or more RLP frames) and the MSC only transmits one RLP acknowledgement frame 117. Since frame number 4 is not found in the transmission buffer, the IWU converts the RLP acknowledgement frame 117 into an LAC acknowledgement

15   frame 118, where the header contains a request for payload unit 4. The MS transmits a new LAC frame where the information field contains payload units 4 to 6 and the header contains payload unit number 4. The IWU stores the RLP frames in the retransmission buffer until it receives acknowledgement from the MSC. If, at some point, the MSC transmits an RLP frame requesting

20   for the retransmission of a frame, the IWU transmits the requested frame from its retransmission buffer.

By means of the arrangement according to the invention it is possible to avoid problems in handovers even if the IWU changes since the protocols stay the same at the connection end points (the MSC and the MS)

25   and there is no need to reset protocol state machines. Both the MS and the MSC know which frames have already been received and acknowledged.

Figure 12 shows an example where an MS is handed over from the "old" IWU to the "new" IWU during the transmission of an LAC frame. The start resembles Figure 11. The MS transmits to the old IWU an LAC frame 121

30   containing three payload units, numbers 1, 2 and 3. The IWU 100 converts the LAC frame into RLP format and transmits a first RLP frame 122. The MSC transmits positive acknowledgement 123 and the IWU transmits a second RLP frame 124. The MSC also acknowledges this frame (125). Now the MS is handed over to a base station which is connected to the "new" IWU 101, and

35   the RLP connection is set up to the new IWU 101. Therefore the MSC does not receive RLP frame number 3 and the new IWU 101 does not receive

acknowledgement for the third RLP frame. Since the MS does not receive within a predetermined time acknowledgement for payload units 1 to 3 that were transmitted in the LAC frame, an LAC timer expires and the MS retransmits the payload units in an LAC frame 126 to the new IWU 101. The

5   new IWU 101 converts the LAC frame 126 into RLP format and transmits a first RLP frame 127. The sequence number of the first RLP frame 127 is the same as the number of the first payload unit in the LAC frame, i.e. 1. The MSC now knows that it has already received RLP frames 1 and 2 via the old IWU and it requests with an RLP acknowledgement frame 128 the new IWU to

10 transmit RLP frame number 3. The new IWU 101 transmits an RLP frame 129, i.e. frame number 3, and the MSC transmits an RLP acknowledgement frame 130 where frame number 4 is requested for next. Since the IWU does not comprise this frame, the IWU converts the RLP frame 130 into an LAC frame 131, which contains a request to transmit payload unit 4. The LAC frame 131

15 thus acknowledges the LAC frame 126. The handover was thus carried out without the doubling or loss of user data.

In a preferred embodiment of the invention, a header of a frame only comprises one payload number indicating the first payload unit contained in the frame. This is sufficient and minimizes the overhead under normal

20 circumstances. However, in special situations, such as when the data rate changes, it may be necessary to indicate in the frame header the numbers of all the payload units. In the invention this can be implemented by extending the frame header, as illustrated by examples in Figures 13 and 14.

Figure 13 shows a payload number field of a frame (e.g. an LAC

25 frame), which can be extended. The length of the basic field is 16 bits (octets 1 and 2). The payload number (PN) is 14 bits. An H flag indicates whether the header extension is used or not. If the H flag is 0, the header ends in this octet and the next two octets (3 and 4) comprise data (i.e. the beginning of the first payload unit). If the H flag is 1, the next two octets (3 and 4) contain a new

30 payload number. In an embodiment of the invention these additional payload numbers replace the first payload unit. A D flag (data segmentation extension) indicates whether the first payload unit comprises data segmentation information. If the D flag is 1, the first payload unit comprises segmentation information. If the D flag is 0, the first data unit comprises data. The data is

35 typically divided (segmented) into payload units as a continuous flow and it can also be restored by placing the payload units one after another in

numerical order. The data segmentation information is required if the data is segmented in an unusual manner.

Normally the payload unit number field only contains octets 1 and 2 (H=0) indicating the number of the first payload unit in the frame.

5   Under special circumstances, for example when the data rate changes, it may be necessary to retransmit a few payload units "out of sequence" in one or more frames, which means that the payload units in the frames do not have successive numbers. According to an embodiment of the invention, the number field of the header is then extended by one or more 10 numbers. This means that in the last number field H=0 and in the other fields H=1. Figure 14 shows an example of a frame with four individually numbered payload units which take the space of five payload units. Padding PAD (e.g. zerofill) is used to adapt the frame size into a multiple of the basic structure. In Figure 14 the size of the payload unit is 80 bits, the FCS is 16 bits and the 15 basic header is 16 bits. The extended header is 16+3*16=64 bits. The padding PAD is 32 bits (80-3*16), wherefore the frame size corresponds to a basic frame comprising four payload units. Normally the frame size changes when the number of the payload units is altered, in which case the frame size is 16+16+n*80 bits, where n is the number of the payload units. By means of the 20 padding PAD also the length of a frame with an extended header is a multiple of the basic frame.

It is obvious that as the technology develops the basic idea of the invention can be implemented in several different manners. Therefore the invention and the embodiments thereof are not restricted to the examples 25 described above, but they may vary within the scope of the claims.